TITLE: Distributed Collaborative Virtual Reality Framework for System Prototyping and Training

Distributed Collaborative Virtual Reality Framework for System Prototyping and Training

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Introduction

The significant impact Information Technology has made in the lives of most people in the last decade or two is undeniable. Coupled with other enabling technologies, many tasks get accomplished more efficiently and reliably nowadays. However, there are instances where the adoption of these technologies takes longer for variety of reasons. System prototyping and training of war fighters has been an area where enabling technologies can be better utilized.

One of the keys to the success of military operations with the least amount of casualties is a well-trained group of people fighting the war. It is also essential that they are well accustomed to the environment in which they operate and comfortable with it. To achieve this, live training would be ideal in almost all cases except where it would pose a significant safety risk. This, of course, is not possible in reality as the resources available for training is limited in the real world.

In this paper, we address the use of enabling technologies in the military and describe a framework that takes advantage of several state-of-the-art technologies to perform combat system design, evaluation and training. The framework uses virtual reality and distributed computing technologies to provide users (trainees, trainers, or combat system designers) an immersive environment to interact with the combat system and the other users. The framework allows participants to collaborate on the same mission or activity in the virtual environment without the need to be at the same geographical location.

There are numerous benefits to systems based on this framework. It is possible to bring together participants into the same virtual environment as opposed to doing this in the physical world that may be costly and sometimes difficult logistically. The cost of training is significantly cheaper since the initial cost and maintenance of computer equipment is usually less than the cost of real combat systems. The framework allows new weapon systems, for example a combat information center, to be built virtually so that users can conduct a walk-through and make suggestions on the design of the system. In other words, the end users can actively participate in the early design phase of a new combat system.

Virtual Engineering

We use the term *Virtual Engineering* to describe the engineering process primarily performed in a Virtual Reality (VR) environment. Virtual Engineering can be utilized at various phases of the development life cycle including requirements, design, development, testing and training. Virtual Engineering allows C4I concepts and combat systems to be evaluated before they are physically built, resulting in significant savings for the US Department of Defense.

There are a number of enabling technologies that we use to make Virtual Engineering effective (See Figure 1). At the top of the list is Virtual Reality. Virtual Reality technologies allow users to immerse themselves into the environment they are working in. What should be noted is that 3D graphics is not always Virtual Reality. What makes the experience almost real or virtually real is usually the human computer interface accompanied with realistic computer graphics.

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Modeling and simulation has found wide acceptance in many engineering fields. Using modeling and simulation, engineers can verify the validity of their design and optimize them. As such, modeling and simulation is an indispensable tool for engineers.

Distributed Computing or Simulations is another technology that is important for the Virtual Engineering of combat systems. Different simulators that the engineers need may have been designed to run on different hardware and they may be running at different physical locations. Therefore, the ability to link all these simulators seamlessly is significant for the Virtual Engineering infrastructure.

Parallel Processing is also an important aspect of modern engineering process. For high precision modeling or for relatively complicated problems, existing computing platforms can be used in parallel to solve problems faster than the alternative of using any one of the computers. Some problems are better suited for parallel processing than others are. However, significant run-time reductions can be obtained by parallel processing in general.

Finally, collaborative environments enable engineers to work on projects synchronously or asynchronously from geographically distant locations. Traditionally, the travel costs discourage teams of engineers who are at different cities or countries to get together and work together as frequently as they would, had they been at the same location. Collaborative environments offer a solution to the problem by allowing engineers to perform video teleconferencing and share documents or applications at the same time.

Virtual Engineering offers a number of advantages over traditional engineering practices. With Virtual Engineering, combat systems can be well understood before resources are committed for building the system. The users or the warfighters can be involved in all phases of the development process early on. Their feedback can save time and money by reducing development life cycle and total development time. Virtual Engineering serves as an integration tool for design, development, integration and testing of systems. In addition, it can be used to train warfighters on the system before the systems are actually built.

Virtual Engineering is well suited for Simulation Based Design and Acquisition (SBD/SBA) applications. Typical SBA life cycle can be divided into four phases: requirement gathering, design, development and testing (See Figure 2).

In the requirement phase, important issue decisions are made in the theater context. For example, what kind of force mix is considered, number of weapon systems to be used in the theater, their search and detection coverage, reaction time, fire power, capacity and weapon load.

In the design phase of the SBA, decisions are made in the platform context. For example, system configuration and connectivity decisions are made based on system requirements. These decisions are then used to determine the types of algorithms, logic and display components to use at element context. This requires simulations that start with simple logic for the requirement formulation phase in the early acquisition process. As the system engineering process progresses into design and development phases, the fidelity and number of entities in the simulation will be greatly increased to meet the needs of system design, development and testing. However, much of the model's fidelity often has to be sacrificed in order to reduce the computational turnaround time and meet the project schedule. In other situations, the fidelity of the model needs to be increased to gain more data and insights for the problem under study, increasing the model's running time. When running on a single processor the simulation faces the "Von Neumann Bottleneck". By taking advantage of recent advances in low cost, high speed computer chips, scalable parallel processors and new software languages, it is possible to have fast turnaround times while still allowing an increase in model fidelity and simulation scenario complexity. A composable simulation model which employs an optimistic parallel processing architecture in which the number of processing nodes can be scaled up or down as needed was developed to meet this need. This enables the analysts to run more experiments or parametric analyses to find the optimal system configuration design within a run time constraint.

The next phase of the SBA process is the testing of the system. An additional benefit of Virtual Engineering is that the testing system can also be used as a training tool for the end-users of the system and let the real users of the system provide feedback early in the life cycle.

It is important to evaluate different components with different characteristics in the development process. For example, to achieve a certain detection coverage characteristics a ship may carry different types and different number of radar systems. The simulation of these radar systems can help identify which system is a better solution to satisfy the requirements. Being able run these simulations in parallel may accelerate system development time significantly.

To practice Virtual Engineering, an object-oriented set of classes has been developed at the Naval Research Laboratory (NRL).

Virtual Reality Framework

An object-oriented set of classes has been developed at the NRL to form a framework for Virtual Engineering and virtual reality applications. The objective of the framework is to allow rapid development of these applications with significant software reuse. We used this framework to demonstrate several concepts that we present in the paper.

Virtual reality is a natural interface between humans and computers, where communication can take the form of moving 3D imagery, sound, and even physical forces (from motion to touch). Virtual reality applications can be so responsive and render imagery in such high speed that the users can feel immersed in the synthetic environment. Many virtual reality applications share common tasks such as rendering geometric models, interfacing with the users, communicating with other users on the network, etc.

The Virtual Reality Framework (VRF) provides several classes that help carry out those tasks, independent of the type of application developed. For example, it implements classes that provide rendering functionality using SGI Iris Performer [1]. Similarly, it implements classes that let the application programmer to use High Level Architecture (HLA) Run-Time Infrastructure (RTI) for communicating with other networked applications or simulations with minimal understanding of the HLA RTI [2–4].

We present two applications that were built using the VRF.

Virtual Prototyping

We used VRF to develop a virtual prototyping application. This tool allows system designers to design and configure the equipment, such as combat consoles, large screen displays, to formulate the layout of room for the ship command center in a collaborative environment. System designers can run the software on a set of networked computers to work on the same system. This process is illustrated in Figure 3. Each person sees the workspace as shown in the lower left of the figure. They may have different types of user interfaces to interact with the software that provides different levels of immersion into the virtual environment. These interfaces range from a simple set of keyboard and mouse to a more advanced interface, such as a workbench or stereoscopic head mounted displays with hand and body movement tracking devices.

This can serve as a digital mockup of the ship command center. In addition, the components that are placed in the virtual ship command center is linked to simulations, so it is possible to interact with the consoles in the command center while running the simulations that the command center system depends on. In other words, it is possible to conduct virtual testing of the configuration using this virtual environment. The same system can also be used to train crewmembers. The costly physical mockup used for ship combat system design and development can be eliminated while reducing the development and testing time. More importantly, the system allows design experts from different disciplines as well as the end users (warfighters) to work as a team and to interact simultaneously during the design. Conflict and design errors can be detected, and resolved at the early stages of the design process. This is especially important because, as studies at the US Defense System Management College have shown, the majority of a system's life cycle cost is determined very early in the design phase of the program.

Having designed the ship command center in the virtual prototyping program, we are able to load the configuration file into another application for testing and training. We describe that application in detail next in a training tool context.

Virtual Combat Information Center Training System

Virtual reality technology has become a cost-effective training alternative with the advent of more powerful and cheaper graphics computers. This technology allows the user to be immersed into a simulated graphical environment where he or she sees the virtual environment through a computer monitor or a head mounted display and provides input through various devices such as a keyboard, mouse or more sophisticated alternatives. We used VRF to develop a distributed virtual CIC for the surface ship training. CIC crewmembers can then perform testing, team learning and training in a virtual ship environment. The virtual environment offers a true interactive 3D view of the interior of the CIC as shown in Figure 4.

The visual simulation portion of the Virtual CIC is intended to provide the "look and feel" of the actual CIC through the use of extensive 3D models and sound clips. Each student appears in the environment as a 3D human representation, an avatar. A picture of each student's face is scanned and texture mapped onto his avatar so that each student can recognize the others inside the Virtual CIC. Networking capability of the Virtual CIC allows students at different geographical locations to train together in a unified virtual environment over a wide area network. This networking capability not only allows the crews in the same ship CIC to be distributed at different locations for training, it also provides the capability to simulate the whole virtual battle group operations as shown in Figure 5 so that different command and control structures can be developed and evaluated.

Various information visualization aids are incorporated into the virtual environment to help crewmembers in understanding and learning different tactical deployment of the combat systems. For example, a *holocube* allows students to visualize the entire battlespace in 3D as shown in Figure 6. This allows crewmembers to correlate sensor data with a visual 3D display of a god's-eye view, facilitating understanding of sensor capabilities and operations. This holographic-like display could also allow for visualization of sensor coverage, emission restrictions, operational boundaries and other doctrinal concepts and entities. As the crewmember changes his watchstation console mode, the holocube view could change to reflect the performance of that mode. This visual augmentation can assist the understanding and teaching tactical deployment of offensive and defensive capabilities. Virtual consoles are easily reconfigured or rearranged as needed for different ship configurations for maximum efficiency. By combining the virtual environment with a ship simulation model, operational procedures under various tactical scenarios can be explored and refined easily. System performance can be stressed in a realistic scenario without the risking accidents or tying up the real operational hardware. Incorporated information visualization aids allow ship crews to learn and understand the operations much faster than in a regular classroom environment. Virtual reality based training also allows students to train with advanced systems before the hardware has been built, or try out new physical layouts that do not currently exist, as well as experiment with and develop new operational procedures. The system described can be applied to land-based or mobile command centers as well as the ship CIC.

Summary

In this paper, we described the approach and benefits of virtual engineering in a distributed environment. We also illustrated two applications that have been developed based on a virtual reality framework to perform virtual engineering, system evaluation and training. The system provides an integrated environment for ship design, prototyping, and testing. This will enhance ship design and operations by exploring different configurations using virtual prototyping techniques coupled with the physics based models. It can also provide means to assess human computer interfaces (HCI) while designing various ship system components. More importantly, this same virtual environment can be used as (1) an assessment tool to evaluate a candidate design's performance; (2) as a means to letting the ship's crew have an early visualization and experience of the new design and provide feedback to the engineers; (3) as a training tool for the ship crew before and after the actual physical system is constructed. This virtual environment can support all phases of the ship life cycle. This approach will permit a much more realistic assessment of a candidate design and system configuration early in the design process. Changes can be made earlier, and therefore easier and cheaper, than in engineering production.

References

[1] IRIS Performer Programmer's Guide, Document Number 007-1680-040, SGI, Mountain View, CA, 1997.

[2] http://hla.dmso.mil.

[3] High Level Architecture Run-Time Infrastructure Programmer's Guide, RTI 1.3 Version 6, DMSO, March 12, 1999.

[4] High Level Architecture Interface Specification, Version 1.3, DMSO, April 2, 1998.

[5] http://www.microsoft.com/windows/netmeeting.

[6] http://manimac.itd.nrl.navy.mil/Ivox.

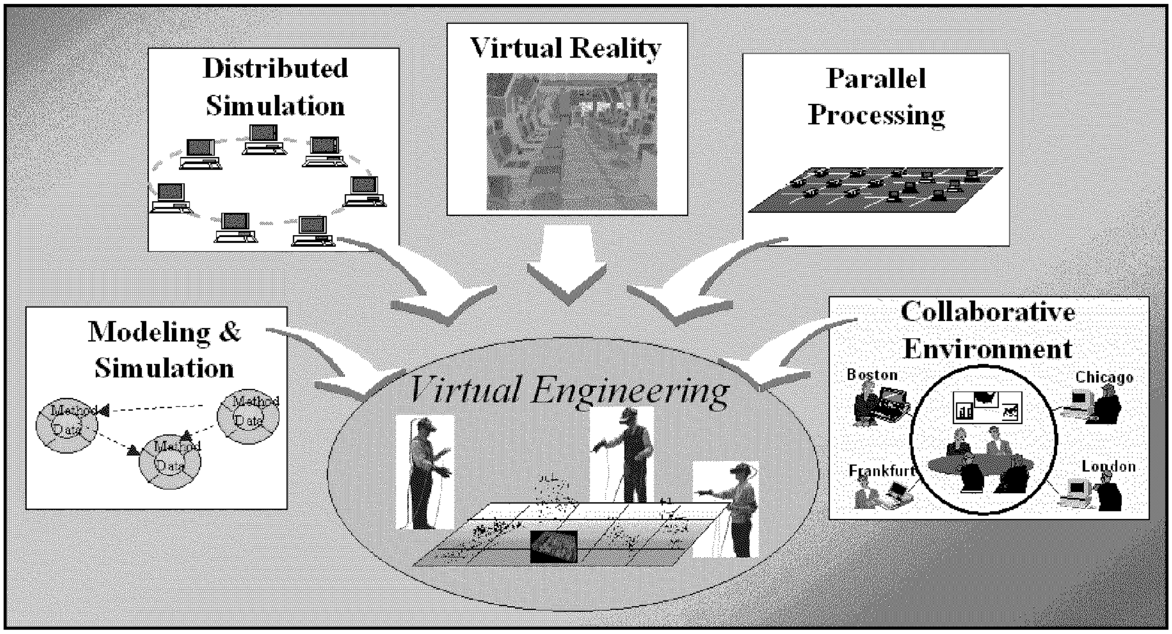

Figure 1: Virtual Engineering Technologies

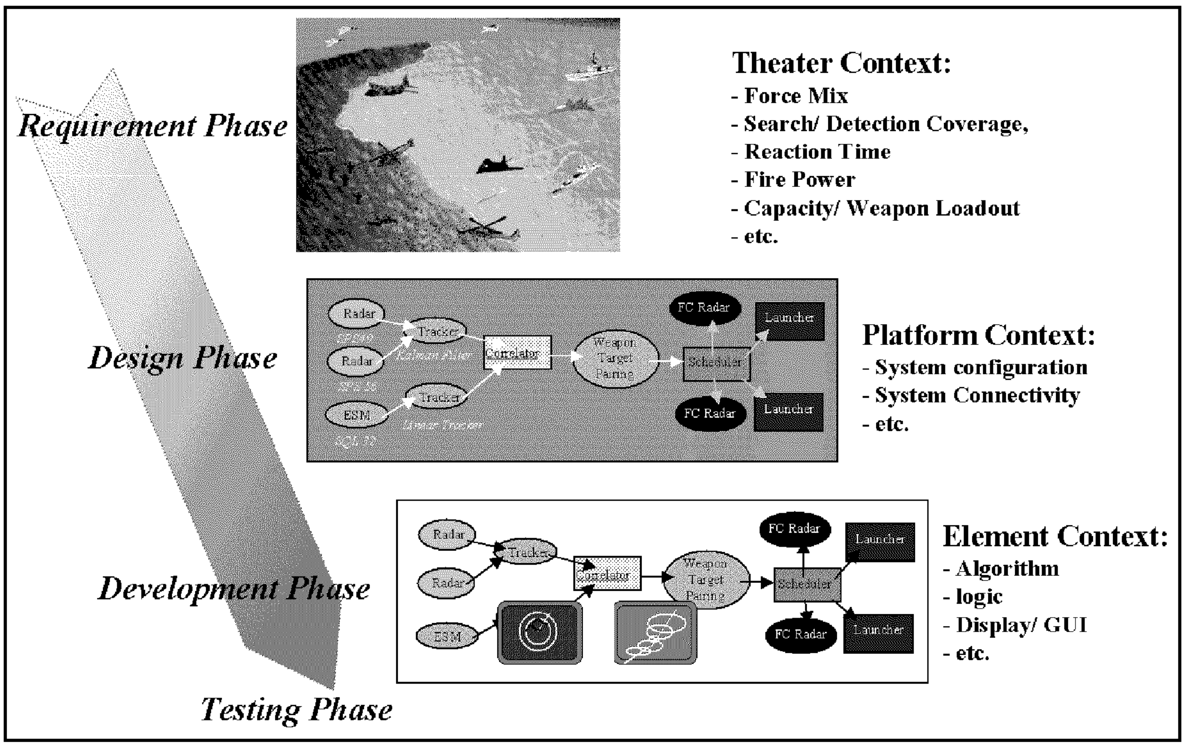

Figure 2: Virtual Ship Combat System Component Development for Acquisition Process

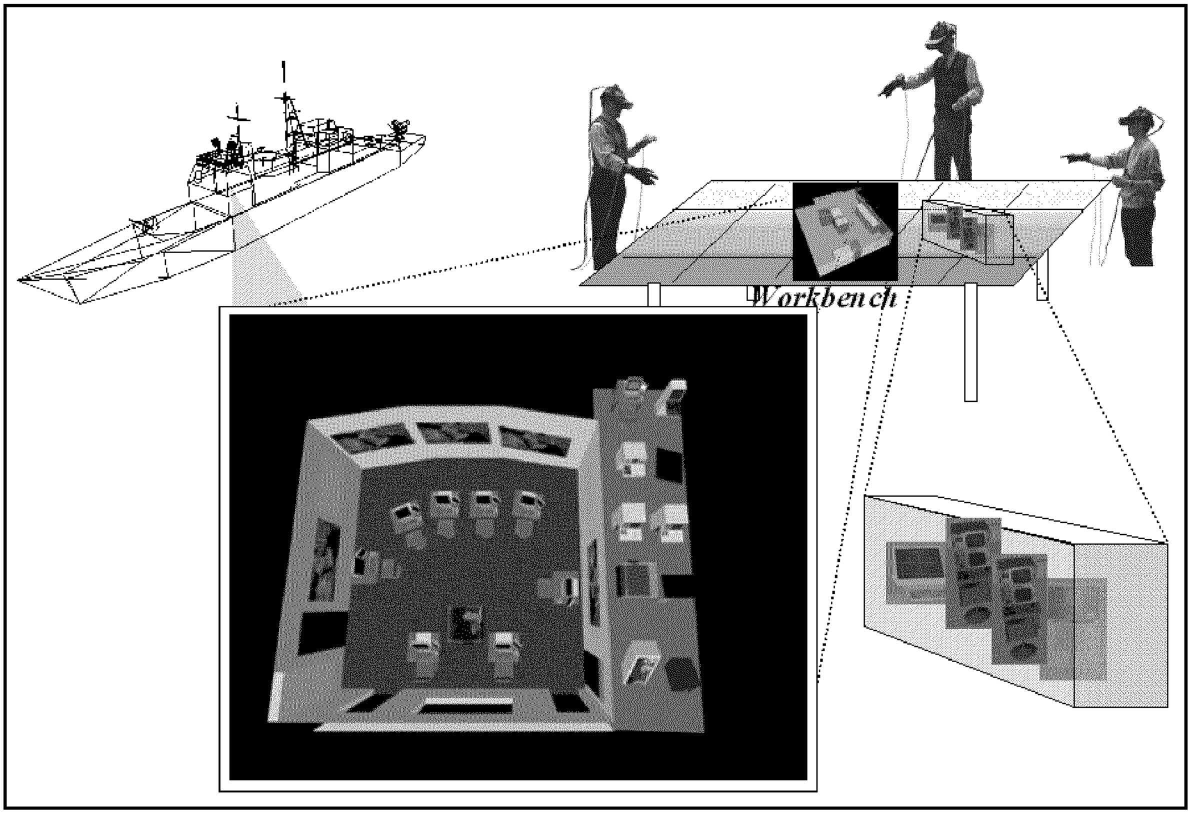

Figure 3: Virtual Prototyping in a Team Setting

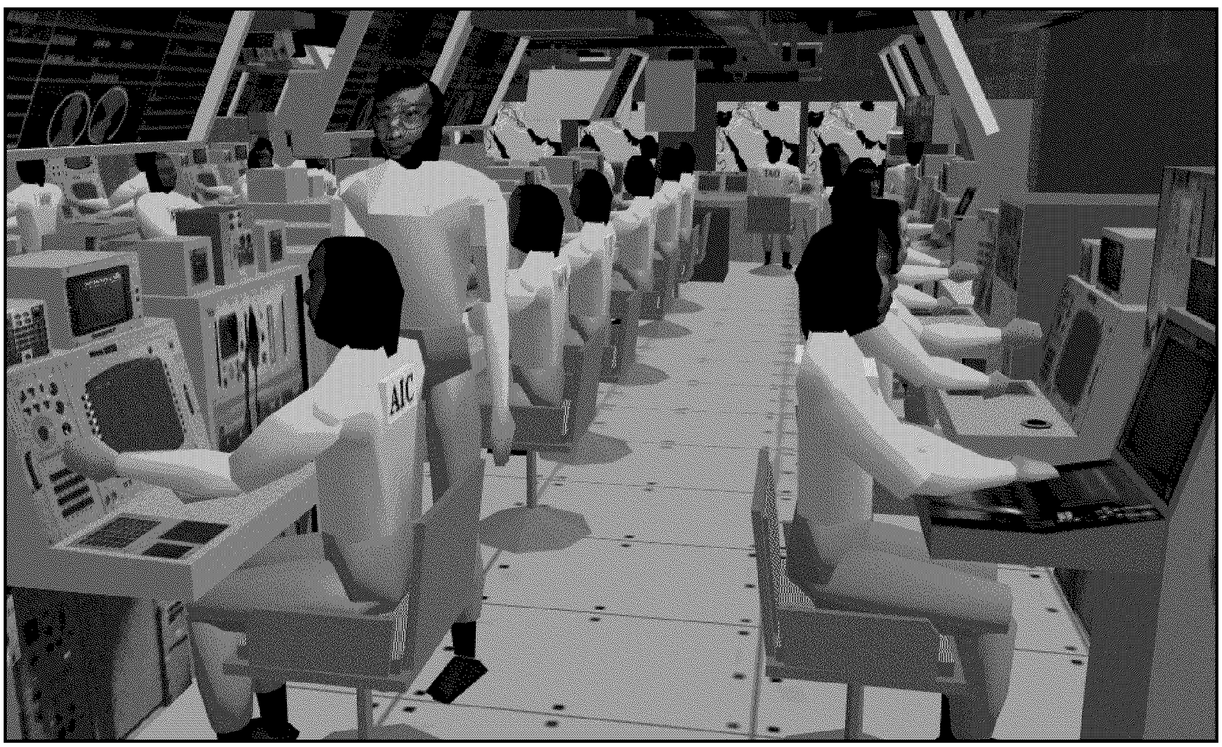

Figure 4: Virtual Ship Combat Information Center

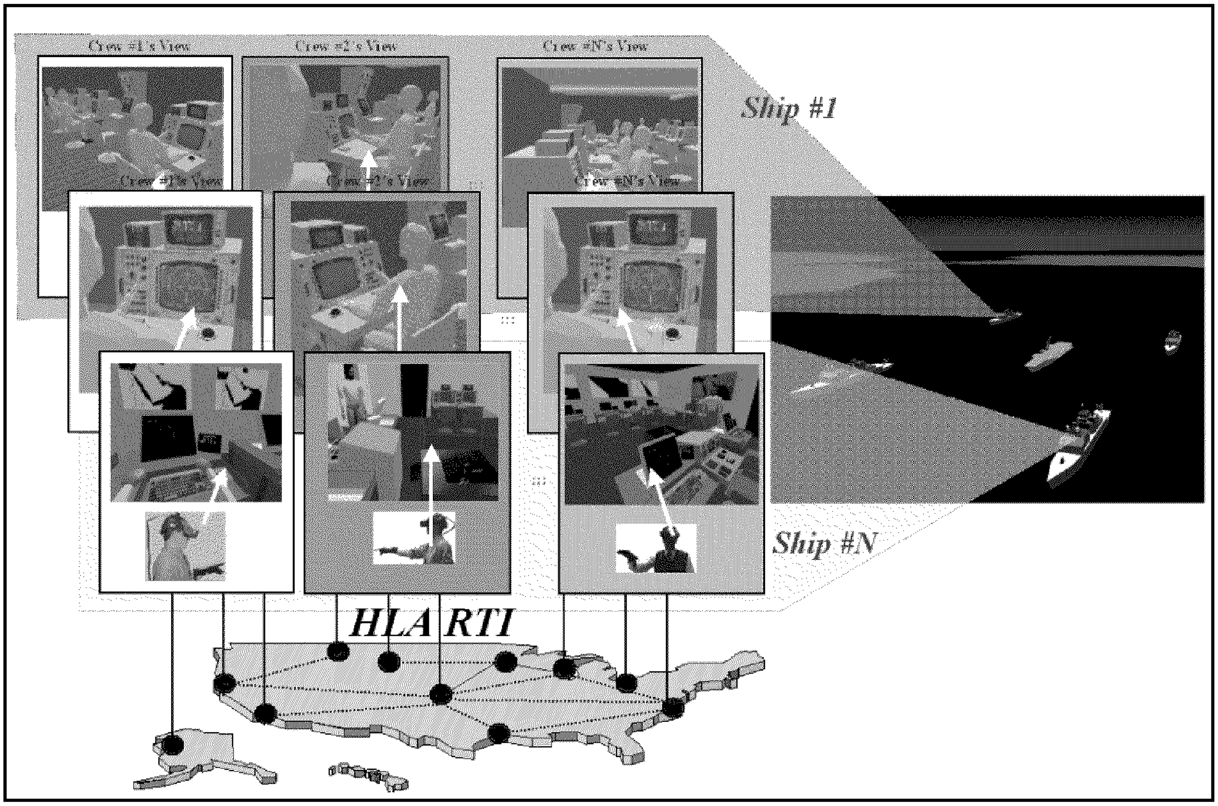

Figure 5: Virtual Battle Group

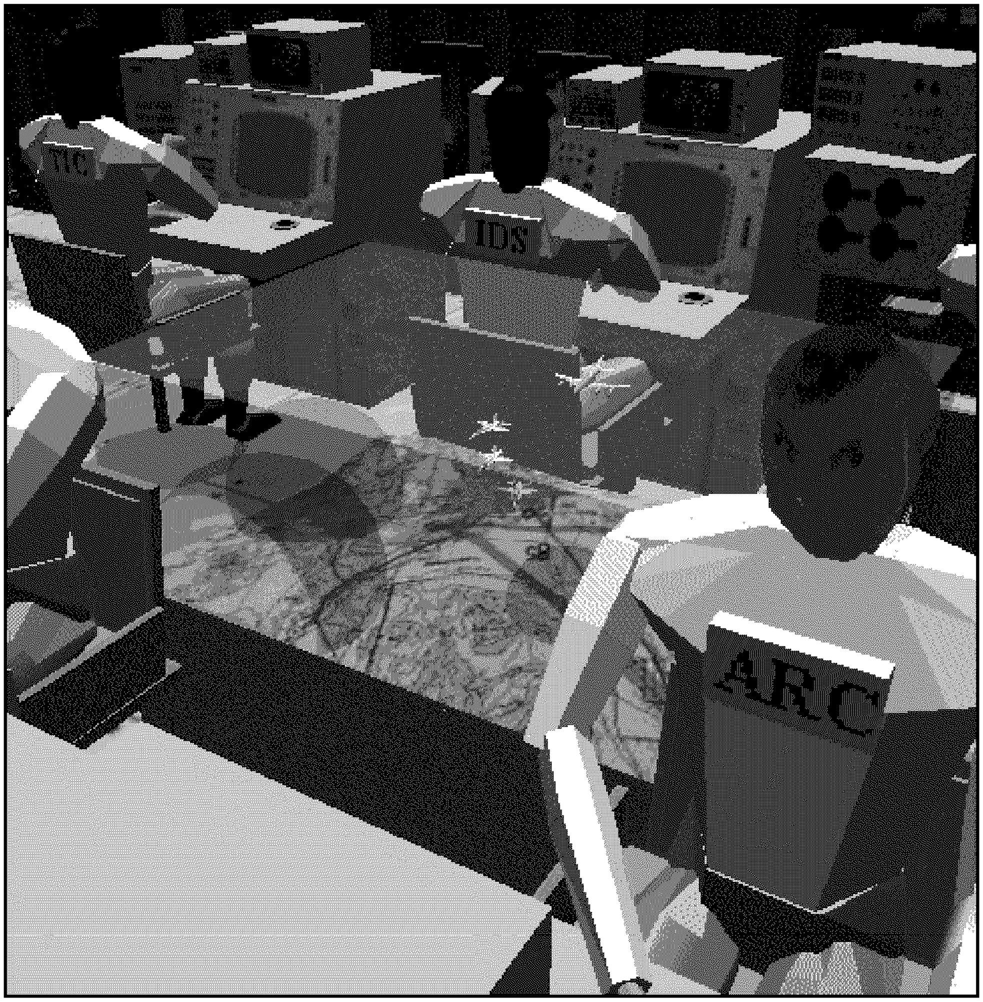

Figure 6: Holocube Visualization Aid